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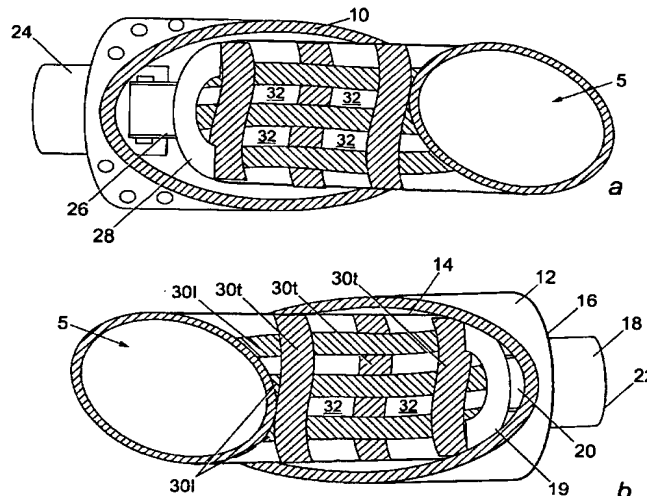
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(54) Title: WELL SCREEN



(57) Abstract: A screen system (5) for underground wells, and a method of fluid flow control and/or sand production control in a well is described. The screen system (5) may include an inner screen (14) and an outer screen (12) having a plurality of slots (32). A mechanism (18), which may include a motor, is provided to vary the size of the said slots (32), and may achieve this by rotating one end (19) of the inner screen (14) relative to the other end (28). An external screen shroud (10) may also be provided and the rotatable mechanism (18) may be controlled by a controller coupled to electromechanical sensors mounted on one or more portions of the screen system (5), where the controller may employ a solids prediction model and a plugging tendency model to calculate a control action.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WELL SCREEN

1

2

3 This invention relates to a screen and in particular
4 a screen for use in oil and gas wells.

5

6 More than 80% of oil and gas clastic reservoirs
7 world-wide are known to be in various stages of
8 unconsolidation which may potentially cause the
9 reservoir to produce sand. This is especially true
10 for reservoirs located in deep waters. Similarly,
11 many of the reservoirs in mature fields are in an
12 advanced state of depressurisation, which makes them
13 susceptible to sand failure. Consequently, at
14 various stages in the economic life of a field, a
15 reservoir located therein will generally require
16 some form of sand control completion. To this end,
17 there is currently an increasing trend towards the
18 use of different screen systems (either barefoot in
19 openhole completions or gravelpack screens) in the
20 completion of wells drilled through reservoirs with
21 sanding problems.

22

1 In an attempt to improve oil or gas recovery at
2 minimal cost from marginal and mature fields,
3 horizontal, extended reach and multilateral wells
4 are becoming the most popular advanced wells for
5 optimal field developments, especially in
6 challenging deep water High Pressure/High
7 Temperature (HP/HT) environments like the Atlantic
8 margin. Sand control in these wells with screen
9 systems (with or without gravelpack), involves
10 placing the selected screen in the well bore within
11 a pay region specifically designed to allow
12 reservoir fluids to flow through the screen slots
13 whilst enabling the screen to filter out formation
14 sand grains. A key part of the screen design
15 therefore is the screen slot gauge, wherein this
16 parameter is estimated by way of the formation grain
17 size distribution. However, any solids loading or
18 sand migration through the slots may lead to
19 plugging and screen erosion with attendant downhole
20 problems including sand production.

21

22 A variety of different generic screen systems are
23 currently in use in the oil industry, such as simple
24 slotted liners, wire wrapped and pre-packed screens,
25 excluder, equalising and conslot screens and special
26 strata pack membrane screens. These screens
27 characteristically have symmetric, fixed geometry
28 slots. However, when these screens are used in
29 advanced wells, the screens are subjected to a non-
30 uniform particulate plugging profile which results
31 in "hotspots" developing in the screen; this is a
32 major concern because it causes erosion of the

1 screen resulting in massive sand production.
2 Follow-up workover operations of such screens are
3 limited to in situ acid washes or vibration or
4 insertion of a secondary slim screen (such as
5 stratacoil) into the damaged screen, which has an
6 adverse affect on reservoir inflow and well
7 performance. Also, retrieval of damaged screens
8 from specially extended-reach wells is almost
9 impossible. Consequently, in adverse conditions,
10 some wells have been abandoned and expensive side-
11 tracks drilled.

12
13 The main difference between the various screen
14 systems currently in use resides in the geometry or
15 configuration of the rigid screen shroud with its
16 fixed, symmetric slots. These systems have
17 different degrees of susceptibility to plugging and
18 operations engineers are usually left with the
19 problem of selecting the most appropriate screen
20 systems to use for specific sand control completions
21 from the range of screen systems currently
22 available.

23
24 Previous work by investigators has shown that the
25 stability and bridging effectiveness of typical
26 filtration media such as screen systems or
27 gravelpacks are functions of operational,
28 environmental and geometric parameters which are
29 largely dependant on the following:

- 30 • Formation grain sized distribution and
31 sorting;

- 1 • Type of reservoir fluids and fluid
- 2 properties;
- 3 • Reservoir drawdown and production; and
- 4 • The geometry of the filtration medium.

5

6 Thus for a defined operating and production rate and

7 drawdown condition, a clastic unconsolidated

8 reservoir will produce sand grains of a particular

9 size distribution which is dependant on the

10 reservoir characteristics. Thus the amount and size

11 distribution of solids contained in a given barrel

12 of fluid produced from an oil or gas well, depends

13 on the bridging effectiveness of the filtration

14 media used in the wells, wherein the bridging

15 effectiveness can be evaluated for defined

16 operational conditions.

17

18 According to the invention there is provided a

19 screen system for underground wells, the screen

20 system comprising a screen:

21 wherein the screen comprises a plurality of

22 slots; and

23 a mechanism capable of varying the size of the

24 said slots.

25

26 According to the invention there is provided a

27 method of fluid flow control and/or sand production

28 control in a well, the method comprising the steps

29 of placing a screen having a plurality of slots in

30 the well and varying the size of the slots.

31

1 Preferably, the screen system comprises a pair of
2 screens comprising a slotted inner screen disposed
3 within a slotted outer screen. Optionally, at least
4 one screen shroud is further provided which is
5 attachable to the outer screen.

6
7 Typically, the inner screen is rotatable relative to
8 the outer screen. Preferably, the inner screen
9 comprises a substantially cylindrical member having
10 a pair of ends wherein one end is rotatable relative
11 to the other end by operation of the said mechanism.
12 Typically, the mechanism comprises a motorised
13 actuator.

14
15 Preferably, the screen comprises a plurality of
16 longitudinally arranged members and at least one
17 transversely arranged member which combine to
18 provide the slots in the interstices therebetween,
19 wherein, rotation of one end of the screen causes an
20 end of the longitudinally arranged members to rotate
21 relative to the other end of the longitudinally
22 arranged members such that the slot size is capable
23 of being varied.

24
25 Preferably at least one screen shroud is provided
26 with electromechanical sensors.

27
28 Preferably, the inner screen is rotated under the
29 control of a controller which is further connected
30 to the electromechanical sensors.

31

1 Preferably the controller employs a solids
2 prediction model to calculate a control action.

3
4 Preferably the controller further employs a plugging
5 tendency model to calculate a control action.

6
7 According to a second aspect of the invention, the
8 screen system is further provided with an external
9 screen shroud.

10
11 Preferably, the external screen shroud is
12 perforated.

13
14 Embodiments of the present invention will be
15 described by way of example only, with reference to
16 the accompanying drawings, in which:-

17 Figure 1a is a side elevation of a bottom
18 section of the screen system, in accordance
19 with the present invention, highlighting a
20 protective shroud, an inner screen and base of
21 the screen, without showing an outer screen;
22 Figure 1b is a side elevation of an upper
23 section of the screen of Figure 1a,
24 highlighting the outer and inner screen without
25 showing the protective shroud;
26 Figure 2 is a block diagram of an architecture
27 for a system for controlling the slot angle of
28 the screen system of Figures 1a and 1b; and
29 Figure 3 is a flow chart showing the different
30 stages in the process of controlling the slot
31 angle of the screen system of Figures 1a and
32 1b.

1 Referring to Figure 1a, a screen system 5 is shown
2 for use in underground wells such as oil and gas
3 wells (not shown), and is provided with an optional
4 external protective shroud 10 substantially
5 comprised of a high grade steel perforated pipe.
6 The external protective shroud 10 acts as a blast
7 protector and helps support any unconsolidated
8 reservoir sand collapse around the screen system 5.
9 The external protective shroud 10 is provided with a
10 high density of perforations of large diameter, this
11 feature minimises the development of any potential
12 hotspots in the screen and provides a maximum area
13 for fluids to flow through.

14
15 In a second embodiment of the invention, the screen
16 system 5 does not require an outer protective shroud
17 10 and is used with a drill-in Liner (DIL) pre-
18 installed within the well.

19
20 Referring to Figure 1b, the shroud 10 (not shown in
21 Figure 1b) encases two concentric slotted screens 12
22 and 14, namely a rigid outer screen 12 and an inner
23 screen 14 wherein the inner screen 14 is
24 telescopically moveable relative to the outer screen
25 12.

26
27 A first end 16, in use upper end 16, of the outer
28 screen 12 is provided with an aperture (not shown)
29 through which a quick connect joint 18 extends. The
30 quick connect joint 18 is sufficiently wide to fill
31 the aperture.

32

1 A first end 19 of the inner screen 14 is provided
2 with a rigid drive shaft 20 which is latchable onto
3 a first end (not shown), in use lower end, of the
4 quick connect joint 18. A second end 22 of the
5 quick connect joint 18 is connectable to a hydraulic
6 motordrive shaft (not shown) or electrohydraulic or
7 electromagnetic actuator via a second quick connect
8 joint to actuate or turn the upper end 19 of the
9 inner screen 14 to a specified angle.

10

11 The quick connect joints at each end of the outer
12 screen 12 have bearings that permit rotation of the
13 inner screen 14. The inner screen 14 is driven by
14 means of the drive shaft 20 at the upper end of the
15 outer screen 12, which is urged by the
16 electromagnetic/electrohydraulic actuator.

17

18 A swivel base 24 is welded to a second end (not
19 shown), in use lower end, of the inner screen 14. A
20 first end 26, in use upper end 26, of the base
21 swivel 24 is attachable e.g. via a latch (not shown)
22 to a second end 28, in use lower end 28, of the
23 outer screen 12 to allow for minimal torque rotation
24 of the inner screen 14. The first end 26 of the
25 base swivel 24 and thus the lower end 28 of the
26 inner screen 14 will normally remain stationary
27 since the base swivel 24 has relatively high
28 internal friction, but the minimum torque rotation
29 feature has the advantage that the first end 26 and
30 thus the lower end 28 of the inner screen 14 can
31 rotate if the electrohydraulic actuator becomes
32 stuck because, for example, sand is causing the

1 upper end 19 of the inner screen 14 to stick. This
2 feature prevents the electrohydraulic or
3 electromagnetic actuator from burning out.

4

5 Alternatively the overtorquing can be restrained by
6 frictionless bearings and the swivel, thereby
7 preventing the motor from burning out.

8

9 Returning to Figure 1a, the outer screen (not shown)
10 and the inner screen 14 are provided with an
11 interwoven lattice of outer screen shroud (not
12 shown) and inner screen shrouds 30 respectively.
13 Each shroud comprises a series of longitudinally
14 arranged bands of material, such as steel of
15 different grades selected in accordance with the
16 well conditions. The bands are coated with micro-
17 electromechanical system sensors (not shown) wherein
18 each sensor is electronically linked to a control
19 system (not shown). The respective lattice of outer
20 screen shroud (not shown) and inner screen shrouds
21 30 comprise a series of longitudinally arranged
22 bands of material 301 which are spaced apart around
23 the circumference of the respective outer 12 and
24 inner 14 screens and extend parallel to the
25 longitudinal axis of the screen system 5.
26 Additionally, the respective lattice of outer screen
27 shroud (not shown) and inner screen shrouds 30
28 comprise a series of transversely arranged rings of
29 material 30t which are spaced apart along the
30 longitudinal axis of the screen system 5 and which
31 are arranged to lie on planes perpendicular to the
32 longitudinal axis of the screen system 5.

1 Accordingly, there are a plurality of slots 32
2 provided in the interstices between the
3 longitudinally arranged bands of material 30l
4 transversely arranged rings of material 30t, where
5 the size of the slots 32 of the inner screen 14 can
6 be varied whilst the screen system 5 is in situ in
7 the well, as will be described subsequently.

8
9 Accordingly, operation of the electrohydraulic
10 actuator rotates the upper end 19 of the inner
11 screen 14 relative to the lower end 28 of the inner
12 screen 14, which results in variation of the size of
13 the plurality of slots 32 of the inner screen 14.

14
15 Figure 2 is a block diagram of the architecture of a
16 system for controlling the screen system 5. The
17 micro-electromechanical system sensors of the screen
18 system 5 are electronically linked to a measurement
19 system 40 which is in turn connectable to a
20 monitoring system 42 and an adaptive controller 44.
21 The adaptive controller 44 is also provided with
22 input data 46 relating to a desired value of a
23 measurable variable of the screen system 5. The
24 adaptive controller 44 is further connected to the
25 screen system 5 and the monitoring system 42.

26
27 Figure 3 is a flow chart of the processes occurring
28 within the screen system 5 and control system. In a
29 first step 50 well data, production data, reservoir
30 data, screen sensor data and default data are
31 entered into a computer. The well data comprises

1 details of :

- 2 (I) the geometrical configuration of the well,
3 (ii) the type of completion of the well,
4 (iii) the designed screen O.D. and
5 (iv) gravelpack details if the well employs
6 gravelpack completions.

7

8 The production data comprises details of the
9 production rate and flowing bottom hole pressure.

10 The reservoir data comprises details of the
11 reservoir pressure, porosity, permeability and sand
12 grain size distribution. The screen sensor data
13 comprises details of the fluid flow velocity across
14 the screen system, the pressure drop across the
15 screen system and solids concentration across the
16 screen system. The default data comprises the
17 default screen pressure drop and the default maximum
18 tolerance level for solids production.

19

20 In second step 52 the outer screen slot is pre-set
21 to a standard gauge based on Saucier rule for the
22 particular reservoir sand size distribution. In
23 other words, the outer screen shroud lattice is pre-
24 set prior to introduction of the screen system into
25 the well such that the slots or gaps 32 provided
26 between the longitudinally arranged bands of
27 material 30l and transversely arranged rings of
28 material 30t are set to the required size. In a
29 third step 54 an optimum slot size 32 is computed
30 for a given production rate and solids level. In a
31 fifth step 56 the electrohydraulic actuator is
32 instructed by the control system to rotate the inner

1 screen 14 to a desired angle in order to increase or
2 decrease the area of the slots or gaps 32 in the
3 inner screen 14 through which the fluid from the
4 well can flow. In a sixth step 58 the flow through
5 the screen system 5 and the solids loading on the
6 screen system 5 are continuously monitored by the
7 micro-electromechanical sensors and in a further
8 step 60 compared with the default maximum tolerance
9 level for solids production and the default plugging
10 pressure drop across the screen system 5 which have
11 been computed in accordance with the built in
12 classic models and entered into the computer in
13 stage 50.

14
15 Any difference between the measured variables and
16 the default values of the variables is communicated
17 to the adaptive controller which in a further step
18 62, accordingly activates the electrohydraulic
19 actuator to operate the screen system 5 to minimise
20 the difference between the measured data and the
21 default data. Thus, the electrohydraulic actuator
22 operates the screen system 5 to adjust the slot or
23 gap size 32 of the inner screen 14 in accordance
24 with the output of the adaptive controller, wherein
25 rotation in one direction, for example a clockwise
26 direction, of the upper end 19 relative to the lower
27 end 28 reduces the slot size 32 such that the area
28 through which the production fluids can flow is
29 reduced which will reduce the production fluid flow
30 rate. Conversely, rotation of the upper end 19
31 relative to the lower end 28 in the other direction,
32 for example a counter-clockwise direction, increases

1 the slot size 32 of the inner screen 14 such that
2 the area through which the production fluids can
3 flow is increased which will increase the production
4 fluid flow rate.

5
6 The adaptive controller calculates an appropriate
7 control action by way of a solids production
8 prediction model and a plugging tendency model. The
9 solids production prediction model is based upon the
10 principal that the degree of solids production or
11 migration through a downhole solids control system
12 depends upon the bridging effectiveness of the
13 control system whether the control system be
14 gravelpack or barefoot screen.

15
16 The degree of solids production or migration through
17 a downhole solids control system is a function of a
18 number of variables including:

- 19 1. The formation of grain size distribution, shape
20 and density.
- 21 2. The type and properties of reservoir fluid.
- 22 3. The fluid production rate or injection rate
- 23 4. The overall well drawdown.
- 24 5. The accumulative production
- 25 6. The hole angle
- 26 7. The type of completion.

27
28 Accordingly the solids production is computed from
29 an established mechanistic prediction model.

30

31 Using a set of equations the maximum and minimum
32 grain size invading the screen system 5 can be

1 computed from a given bridging efficiency. The
2 maximum and minimum grain size invading the screen
3 system 5 can be employed with the solids production
4 concentration in a modified Ergun equation for
5 predicting the flow through the filtration system.
6 The plugging tendency model accounts for the effect
7 of time cumulative production and pore blocking
8 mechanisms on the flow filtration system. In the
9 plugging tendency model the plugging tendency is
10 quantified as a function of the pressure drop across
11 the screen system 5, wherein the pressure drop
12 across the screen system 5 is calculated as the sum
13 total of the pressure drop across the screen
14 aperture 32 itself and the pressure drop across the
15 solid filter cake on the screen system 5.

16

17 The invention is not limited by the examples
18 hereinbefore described which may be varied in
19 construction and detail. For example, an outer
20 screen could be omitted, with just an inner screen
21 operating to control the sand production -in this
22 embodiment, the control system would be modified
23 accordingly.

1 CLAIMS:-

2

3 1. A screen system for underground wells, the
4 screen system comprising a screen
5 wherein the screen comprises a plurality of
6 slots; and
7 a mechanism capable of varying the size of the
8 said slots.

9

10 2. A screen system according to claim 1, wherein
11 the screen system comprises a pair of screens
12 comprising a slotted inner screen disposed within a
13 slotted outer screen.

14

15 3. A screen system according to claim 2, further
16 comprising at least one external screen shroud.

17

18 4. A screen system according to either of claims 2
19 or 3, wherein the inner screen is rotatable relative
20 to the outer screen.

21

22 5. A screen system according to any of claims 2 to
23 4, wherein the inner screen comprises a
24 substantially cylindrical member having a pair of
25 ends wherein one end is rotatable relative to the
26 other end by operation of the said mechanism,

27

28 6. A screen system according to any preceding
29 claim, wherein the mechanism comprises a motorised
30 actuator.

31

1 7. A screen system according to claim 2 or to any
2 of claims 3 to 6 when dependent upon claim 2,
3 wherein at least one of the inner and outer screens
4 comprises a plurality of longitudinally arranged
5 members and at least one transversely arranged
6 member which combine to provide the slots in the
7 interstices therebetween.

8

9 8. A screen system according to claim 7, wherein
10 rotation of one end of the said at least one screen
11 causes an end of the longitudinally arranged members
12 to rotate relative to the other end of the
13 longitudinally arranged members such that the slot
14 size is capable of being varied.

15

16 9. A screen system according to any preceding
17 claim, wherein at least one screen or screen shroud
18 is provided with electromechanical sensors.

19

20 10. A screen system according to claim 9 when
21 dependent upon claim 8, wherein the inner screen is
22 rotated under the control of a controller which is
23 further connected to the electromechanical sensors.

24

25 11. A screen system according to claim 10, wherein
26 the controller employs a solids prediction model to
27 calculate a control action.

28

29 12. A screen system according to either of claims
30 10 or 11, wherein the controller further employs a
31 plugging tendency model to calculate a control
32 action.

1

2 13. A screen system according to claim 3 or to any
3 of claims 4 to 12 when dependent upon claim 3,
4 wherein the external screen shroud is attachable to
5 the outer screen.

6

7 14. A screen system according to claim 13, wherein
8 the external screen shroud is perforated.

9

10 15. A method of fluid flow control and/or sand
11 production control in a well, the method comprising
12 the steps of placing a screen having a plurality of
13 slots in the well and varying the size of the slots.

14

15 16. A method according to claim 15, wherein a
16 mechanism is provided to vary the size of the said
17 slots.

18

19 17. A method according to claim 16, wherein the
20 mechanism is capable of rotating a first portion of
21 the screen relative to a second portion of the
22 screen to vary the size of the said slots.

23

24 18. A method according to any of claims 15 to 17
25 wherein a controller controls the actuation of the
26 rotation mechanism.

27

28 19. A method according to claim 18, wherein the
29 controller is provided with data inputs from one or
30 more sensors provided downhole.

31

1 20. A method according to claim 19, wherein the
2 sensors are mounted on one or more portions of the
3 screen system.

4

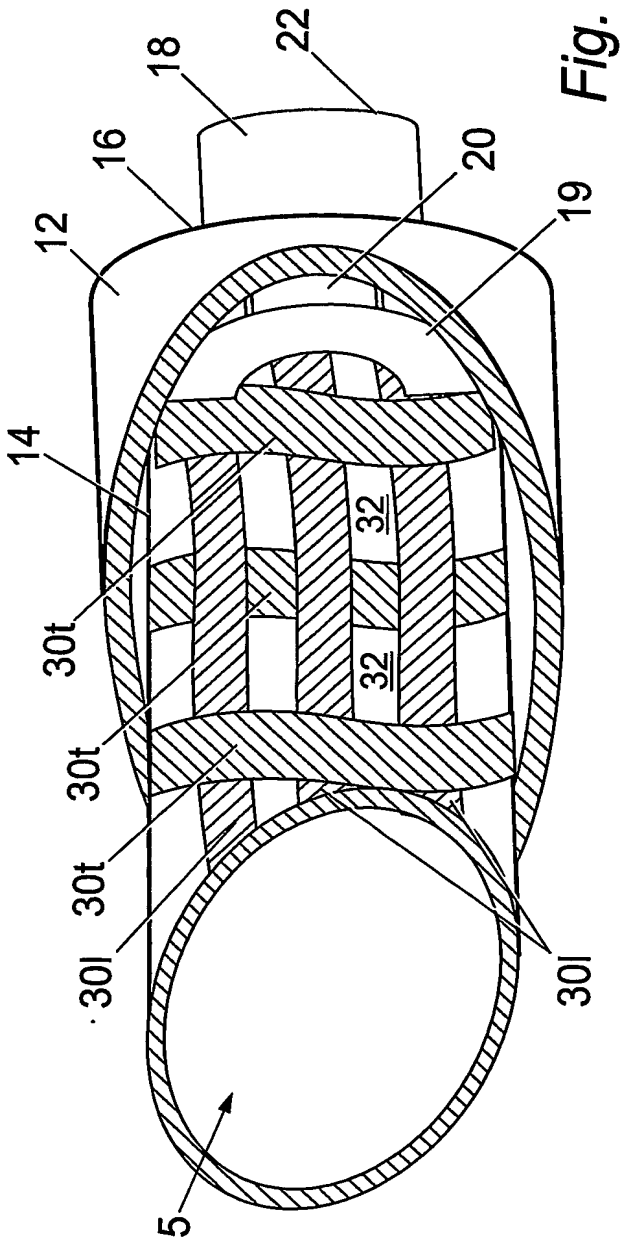
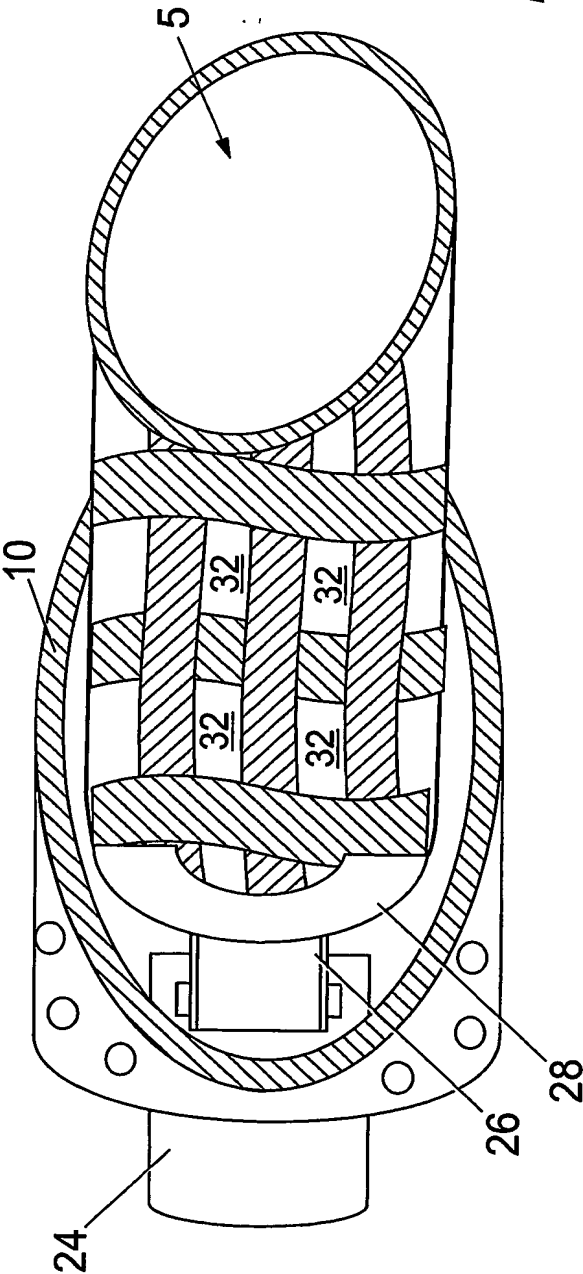
5 21. A method according to either of claims 19 or
6 20, wherein the sensors are electro-mechanical
7 sensors.

8

9 22. A method according to any of claims 18 to 21,
10 wherein the controller employs a solids prediction
11 model to calculate a control action.

12

13 23. A method according to claim 22, wherein the
14 controller further employs a plugging tendency model
15 to calculate a control action.



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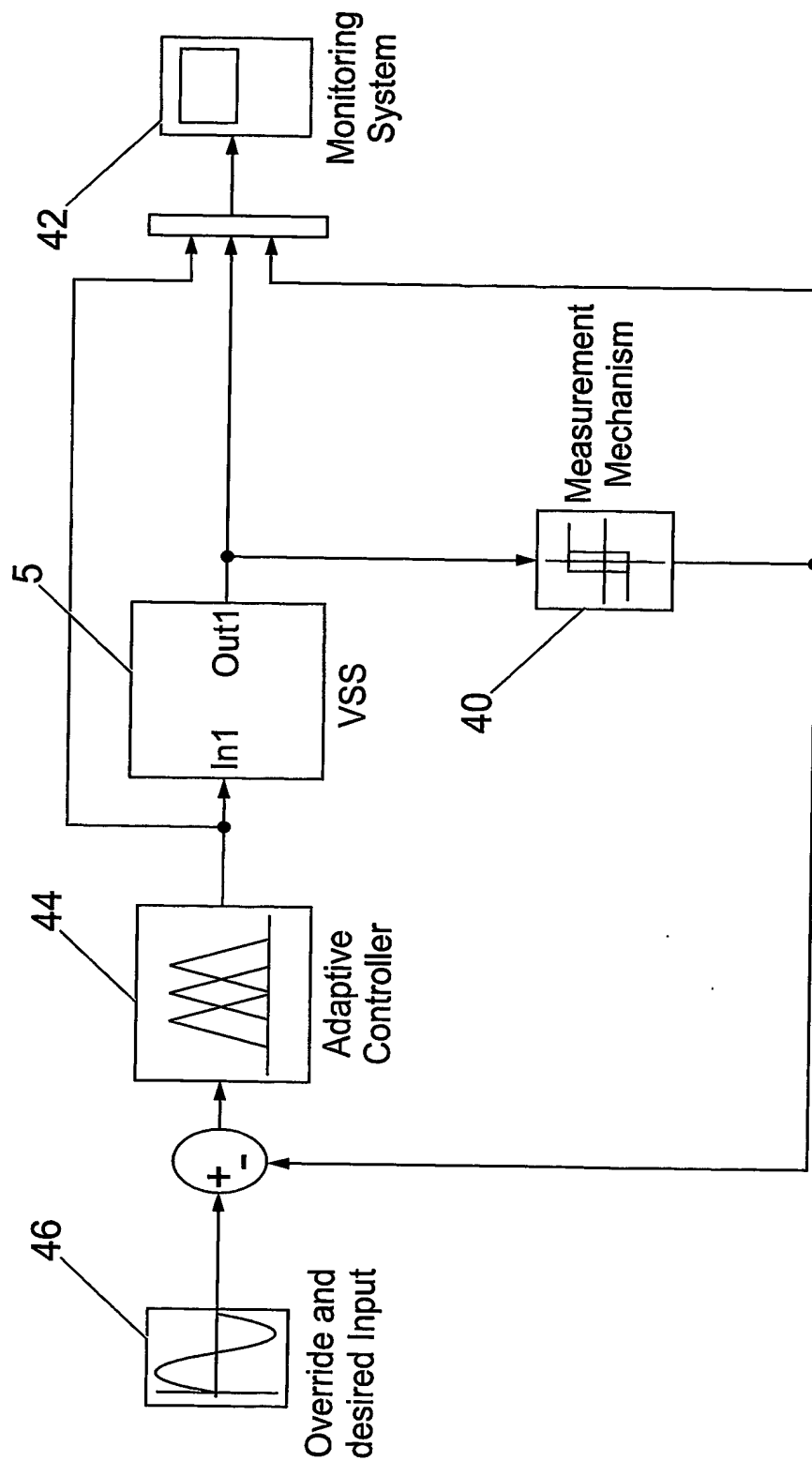
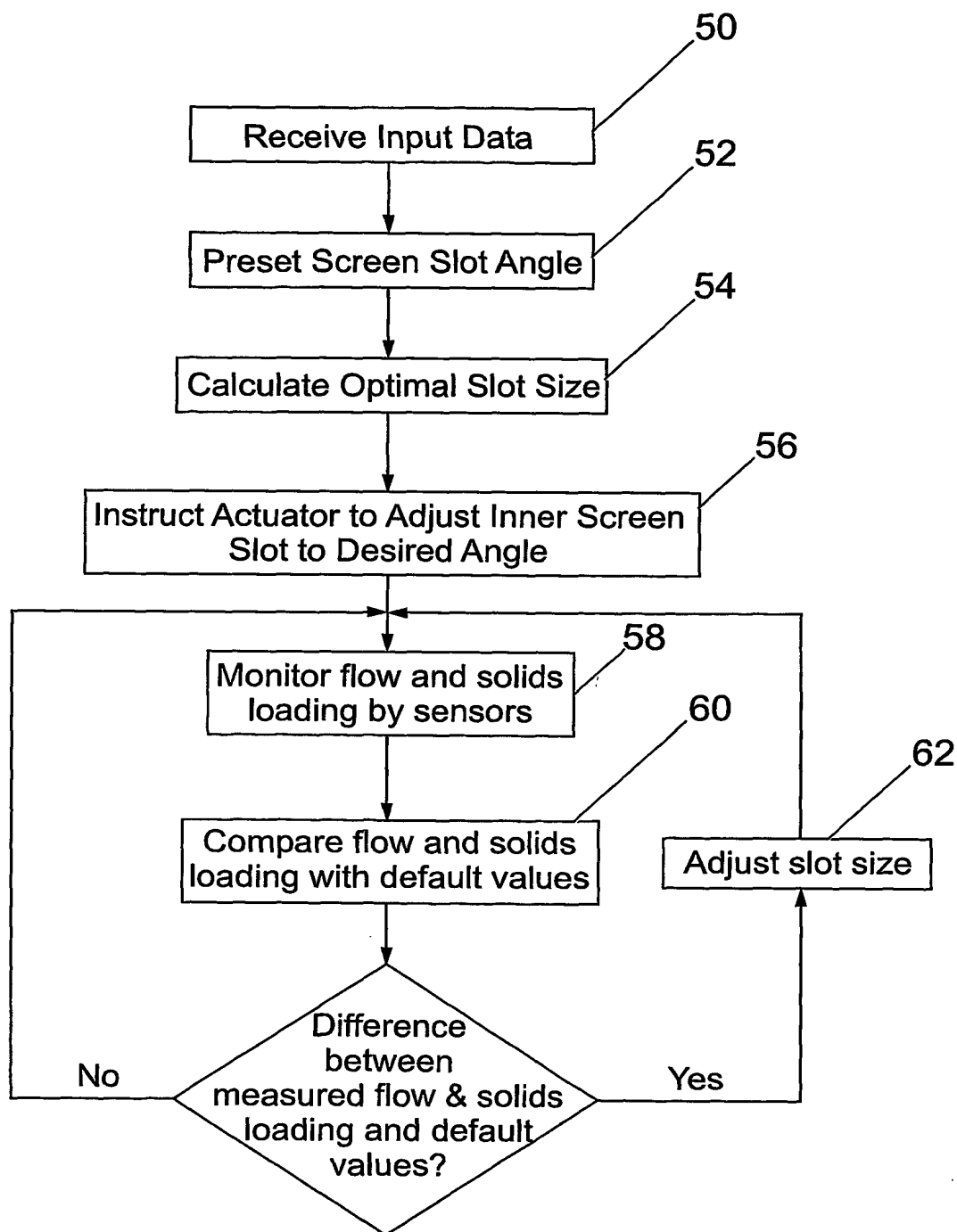


Fig. 2

3 / 3

*Fig. 3*

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 03/03896

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B43/08 E21B43/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B E03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 419 606 A (O.H. JEWELL) 14 January 1890 (1890-01-14) claim 1 figures 1,2	1,2
Y	---	3
Y	US 5 979 551 A (UBAN STEPHEN A ET AL) 9 November 1999 (1999-11-09) column 4, line 2-16 figures 1,5	3
X	US 2 280 054 A (BECK JULIUS S) 21 April 1942 (1942-04-21) column 2, line 49 -column 3, line 2 figures 1,2	1,15-17
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

17 December 2003

Date of mailing of the international search report

13/01/2004

Name and mailing address of the ISA

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Fax: (+31-70) 340-3016

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Schouten, A

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 03/03896

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 638 726 A (SIBLEY DAVID L) 1 February 1972 (1972-02-01) the whole document ---	1, 15
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